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RIVETING

Aluminum

ALUMINUM COMPANY OF AMERICA • PITTSBURGH, PA.

The* RIVETING *of
ALUMINUM
AND
ITS ALLOYS



Rivets

ALUMINUM COMPANY OF AMERICA
Pittsburgh, Pennsylvania

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THE RIVETING OF ALUMINUM AND ITS ALLOYS



RIVETING is a satisfactory method of joining aluminum and its alloys. Either steel or aluminum alloy rivets may be employed. Steel rivets are stronger, but they should be used only when the structure is to be painted adequately. Aluminum alloy rivets are employed where maximum resistance to corrosion and weight saving are essential.

Aluminum alloy rivets may be made from practically any of the wrought aluminum alloys, but the following are the alloys commercially available in rivets: 2S (commercially pure aluminum), 3S, A17S, 17S and 53S.

As the properties of 2S and 3S are not improved by heat treatment, rivets made from them are always driven cold as received from the manufacturer. The other three alloys (A17S, 17S and 53S) have their properties improved by heat treatment and consequently, rivets made from them should always be heat treated* before or during the driving operation, as will be explained later.

Aluminum alloy rivets are furnished with various types of heads. Button, round, mushroom, brazier and flat head rivets are furnished with a small fillet at the junction of the shank and head. The radius of this fillet is equal to about one-tenth of the shank diameter, with a minimum of 0.01 of an inch.

*The heat treatment of 53S is covered by patents owned by Aluminum Company of America

THE STRENGTH OF RIVETED JOINTS

IN a properly designed riveted joint, rivet sizes and spacings are selected so that the force acting on any individual rivet does not exceed the safe design value of the rivet. Safe design values are given in shear, tension and bearing (crushing). They are determined so that an ample margin of safety is provided against each of the three corresponding types of failure.

Safe Shear Value of Rivets:—The first consideration in the selection of the proper rivet is its shear value, which depends upon:

1. Its cross-sectional area;
2. The shear strength of the material;
3. The number of planes along which the rivet tends to shear; viz., single shear, double shear.

The cross-sectional area of a driven rivet is an uncertain quantity because hole sizes vary. In addition, the size of the hole is generally increased by the swelling of the rivet when it is upset. Some engineers use the nominal diameter of the rivet for calculating areas and others use the diameter of the hole. In most cases, it seems unnecessarily conservative to base calculations on the nominal diameter of the rivet; therefore, it is recommended that the hole diameter be used up to a limiting value 5 per cent greater than the nominal diameter of the rivet.

In general, the nominal shear strength of the rivet material is a good basis for calculating the shear strength of driven rivets. Actual tests on driven rivets have indicated that in some cases the driving operation increases the shear strength. Advantage has been taken of this fact in Table I.

The number of planes on which a rivet tends to shear depends entirely on the design of the joint. In most cases, rivets are used either in single or double shear, but occasionally they may be used in triple or even quadruple shear. The shear value

of a rivet increases directly as the number of planes upon which shear occurs, so that in double shear a rivet is twice as strong as in single shear.

Table II gives safe design values for various rivets in single shear. These values have been calculated on the basis of a hole diameter 5 per cent greater than the nominal rivet diameter, using safe design stresses taken from Table I.

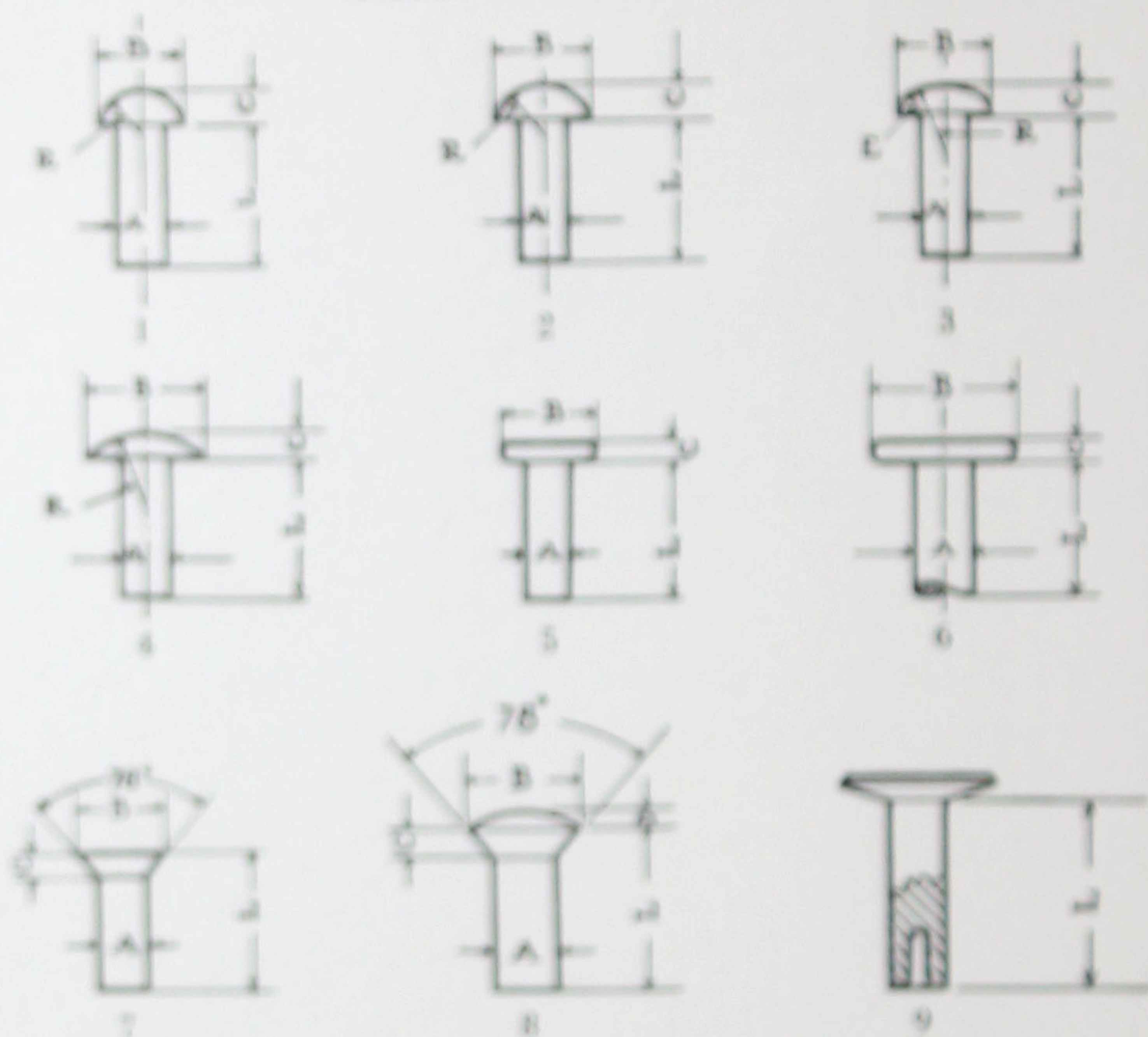
Safe Tensile Value of Rivets:—Rivets are not well suited for transmitting loads in tension because a slight eccentricity of load exerts a prying action on the head which may result in early failure. This tendency is especially marked under the condition of repeated loads. Consequently, it is a generally accepted practice to avoid the use of any connection designed principally

TABLE I—SHEAR STRENGTHS AND SAFE SHEAR DESIGN STRESSES FOR DRIVEN RIVETS

Rivet	Driving Procedure	Average Ultimate Shear Strength Lb. per square inch	Recommended Safe Shear Design Stress,* Lb. per square inch
2S	Cold, As-received	11,000	3,000
3S	Cold, As-received	14,000	4,000
A17S-T	Cold, As-received	30,000	8,500
17S**	Cold, immediately after quenching	35,000	10,000
53S-W	Cold, As-received	25,000	7,000
53S-T	Cold, As-received	28,000	8,000
17S**	Hot, 930° to 950°F.	34,000	9,000
53S**	Hot, 960° to 980°F.	20,000	6,000
Steel	Hot, 1700° to 1900°F.	45,000	13,000

*These values have a factor of safety of about 3.5.

**Immediately after driving the shear strengths of these rivets are about 75% of the values shown. On standing at ordinary temperatures they age harden to develop their full strengths, this action being completed in about four days.

COMMON TYPES OF HEADS SUPPLIED ON
ALUMINUM ALLOY RIVETS

Kind	Width B	Head Depth C	Head Radius R	Edge Radius E	Oval Depth D
1 Button Head	1.75A	0.75A	0.885A	.....	.....
2 Round Head	2A	0.75A	1.042A	.....	.....
3 Mushroom Head	2A	0.625A	1.684A	0.50A	.....
4 Brazier Head	2.50A	0.50A	1.8125A	.....	.....
5 Flat Head	2A	0.40A	.....	.....	.....
6 Tinnere's Rivet	2.25A	0.30A	.....	.....	.....
7 Cask Head	1.81A	0.50A	.....	.....	.....
8 Cask Oval Head	1.81A	0.50A	1.7656A	.....	0.25A
9 Tubular Shank	This rivet made with several sizes of heads.				

for transmitting loads by tension in the rivets. Tensile stresses in rivets cannot always be avoided because the racking of the framework and other secondary effects may produce appreciable tensile loads. In such cases, the safe tension value of a rivet may be taken as one-half the safe single shear value. (See Tables I and II.) Always an effort should be made to keep such secondary tensile stresses in rivets as low as possible.

Safe Bearing Value of Rivets:—The bearing value depends upon:

1. The area in bearing.
2. The bearing strength of the metal in the rivet or plate, whichever is the lower.
3. The edge distance in the direction in which the joint is stressed.

TABLE II—SAFE DESIGN VALUE OF ONE RIVET IN SINGLE SHEAR, LB.

Factor of safety of about 3.5.

Diameter of hole assumed 5 per cent greater than diameter of rivet.

For double shear values, multiply by two.

Size, inches	Cold Driven						Hot Driven		
	2S	3S	A17S-T	17S*	53S-W	53S-T	17S	53S	Steel
$\frac{1}{4}$	160	220	460	540	380	430	.....	.....	700
$\frac{3}{8}$	370	490	...	1,220	850	980	1,100	730	1,590
$\frac{1}{2}$	650	860	...	2,160	1,510	1,730	1,940	1,300	2,800
$\frac{5}{8}$	1,010	1,350	...	3,380	2,370	2,710	3,040	2,030	4,400
$\frac{3}{4}$	1,460	1,940	...	.....	3,410	.....	4,370	2,920	6,320
$\frac{7}{8}$	1,990	2,660	...	.....	.....	.....	5,980	3,980	8,630
1	.....	.....	...	.....	.....	.....	7,790	5,190	11,250

*Driven immediately after quenching.

TABLE III—SAFE BEARING DESIGN STRESSES FOR ALUMINUM ALLOY PLATES AND SHAPES

These values should be used only when the edge distance measured from the center of rivet hole in the direction of stressing is equal to or greater than twice the diameter of the rivet hole. For smaller edge distances values should be reduced proportionately.

These values have a factor of safety of about two against permanent distortion of the rivet hole and, when the foregoing restrictions are applied, they have a factor of safety of about four against crushing failure.

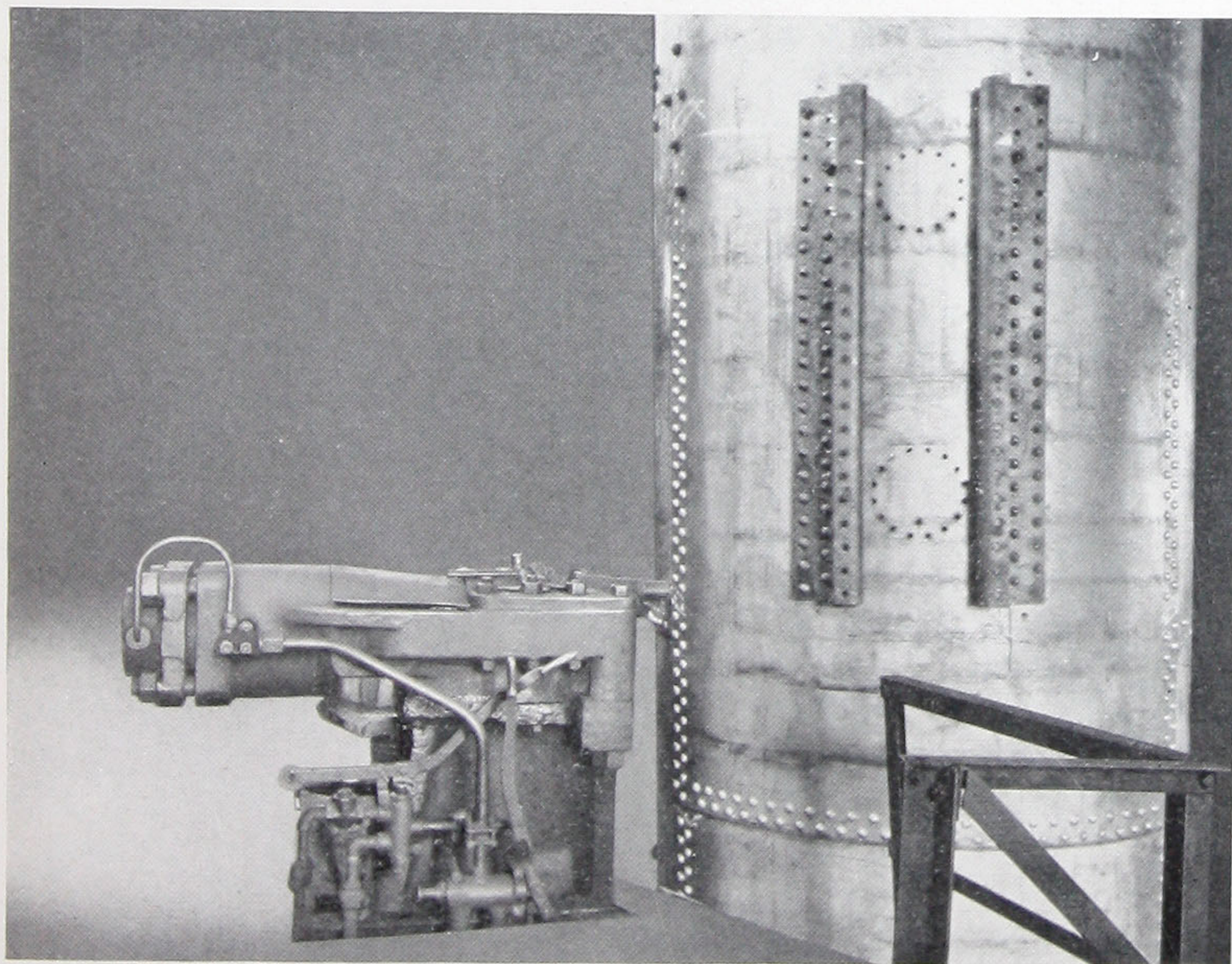
Alloy	Safe Bearing Design Stress, Lb. per square inch	Alloy	Safe Bearing Design Stress, Lb. per square inch
2S-O	5,000	A17S-T	19,000
2S- $\frac{1}{2}$ H	7,000	17S-T	26,000
2S-H	10,000	24S-T	29,000
3S-O	7,000	27S-T	26,000
3S- $\frac{1}{2}$ H	9,000	51S-W	15,000
3S-H	13,000	51S-T	21,000
4S-O	11,000	52S-O	13,000
4S- $\frac{1}{2}$ H	14,000	52S- $\frac{1}{2}$ H	15,000
4S- $\frac{3}{4}$ H	15,000	52S- $\frac{3}{4}$ H	17,000
4S-H	18,000	52S-H	18,000
		53S-W	14,000
		53S-T	18,000

The area in bearing is the thickness of metal times the diameter of hole. It is recommended that for calculating bearing areas the hole diameter be taken not greater than 1.05 times the nominal rivet diameter.

The ultimate bearing strength of aluminum alloys in contact with driven rivets is about 1.5 times the nominal tensile strength of the metal, provided the edge distance in the direction of stressing is equal to at least twice the diameter of the hole, the edge distance being measured from the center of the hole. For smaller edge distances, the bearing strength drops off about in proportion to the decrease in edge distance, so that for an edge distance of one and one-half diameters the bearing strength is about three-quarters of that for an edge distance of two diameters.

Bearing tests of joints show that the first appreciable permanent distortion of the hole occurs when the bearing stress is approximately equal to the nominal tensile strength of the material and that this yielding is practically independent of the edge distance. The safe bearing design stresses for various aluminum alloys given in Table III have an adequate factor of safety against both hole distortion and ultimate failure.

The safe bearing stresses for driven rivets given in Table IV are to be used only when the rivet is softer than the material through which it is driven. For instance, if $\frac{1}{4}$ -inch 4S- $\frac{1}{2}$ H plates are joined by $\frac{1}{2}$ -inch 53S-W rivets driven in $\frac{17}{32}$ -inch diameter holes spaced $1\frac{1}{4}$ inches from the edge of the plates, the safe bearing value is governed by the rivets and is 1840 lb. ($1.05 \times \frac{1}{2} \times \frac{1}{4} \times 14,000$). If the same rivets are used in 4S-O plates, the safe bearing value is governed by the plates and is only 1440 lb.



Riveting Aluminum Alloy Tank, $\frac{3}{4}$ inch Hot Aluminum Alloy Rivets.

($1.05 \times \frac{1}{2} \times \frac{1}{4} \times 11,000$). In the first case, if the edge distance had been only $\frac{7}{8}$ inch, the plate would have governed and the value would have been 1620 lb. $\left(1.05 \times \frac{1}{2} \times \frac{1}{4} \times 15,000 \times \frac{\frac{7}{8}}{2 \times \frac{1}{4}}\right)$.

TABLE IV—SAFE BEARING DESIGN STRESSES FOR
DRIVEN RIVETS

These values to be used only when smaller than corresponding value for metal in contact with rivets as taken from Table III.

Rivet	Driving Procedure	Safe Bearing Design Stress, lb. per square inch
25	Cold, As received	7,000
35	Cold, As received	9,000
A17S-T	Cold, As received	10,000
17S	Cold, immediately after quenching	26,000
58S-W	Cold, As received	14,000
58S-T	Cold, As received	18,000
17S	Hot, 930° to 950° F.	26,000
58S	Hot, 960° to 980° F.	14,000
Steel	Hot, 1700° to 1800° F.	30,000

PROPORTIONS OF RIVETED JOINTS

THE first requirement of riveted joints is that they be strong enough to transfer safely the forces acting on the parts joined. This requirement is responsible only in a general way for the design of the joint, because a number of joints can be designed for any given case, all strong enough, but varying widely in size and spacing of rivets. In the following paragraphs, the factors influencing the proportions of riveted joints are discussed. Such factors will be found helpful in laying out highly stressed joints, as well as those in which the rivets are used simply to fasten two or more parts together.

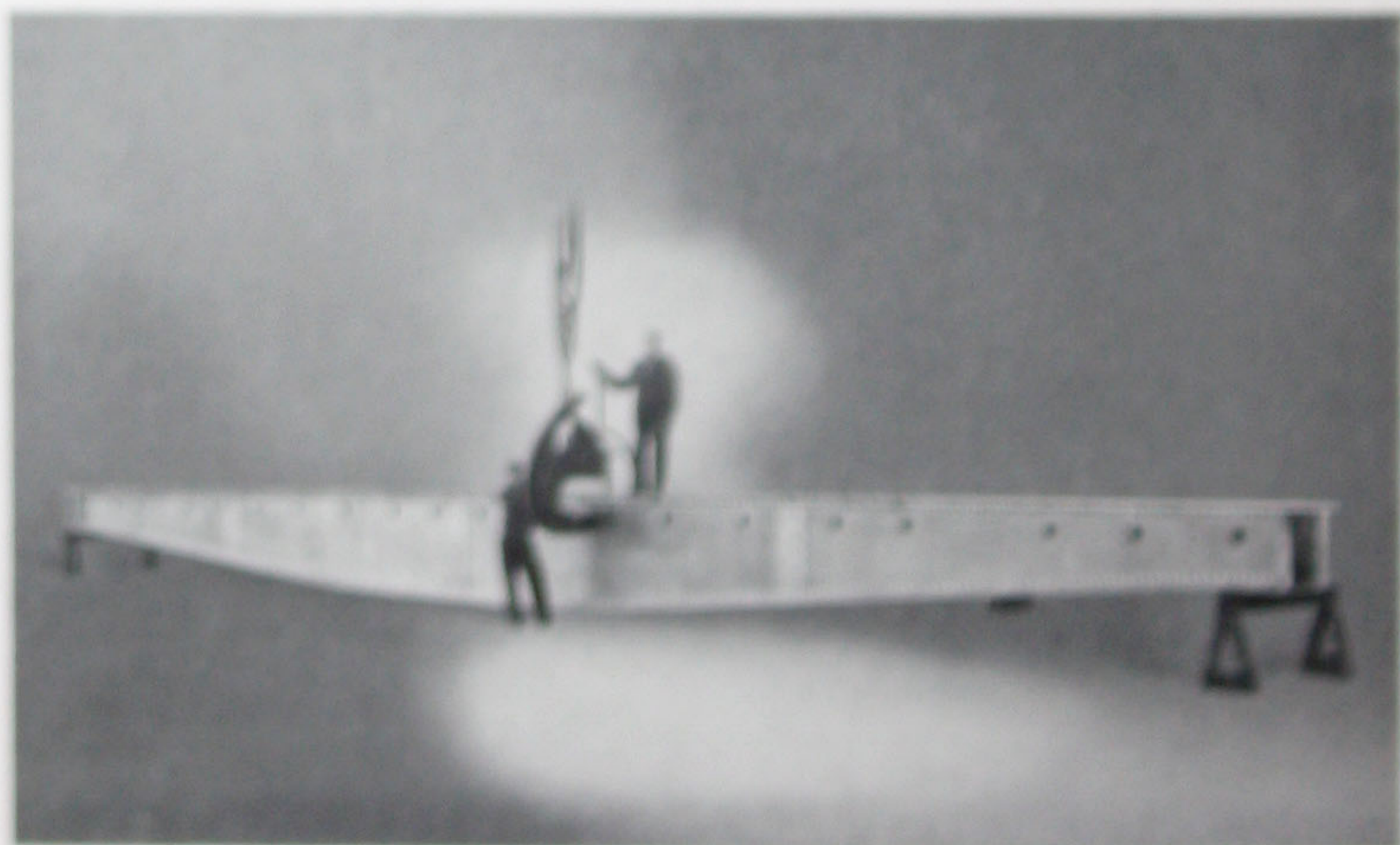
*Size of Rivet, Maximum and Minimum Limits:—*If a large rivet is used in thin metal, the bearing strength usually governs and there is an excess of shear strength. Moreover, the pressure required to drive the large rivet frequently causes an undesirable bulging of the thin material around the rivet head. For these reasons, the diameter of the rivet should rarely exceed two and one-half to three times the thickness of the sheet or plate.

On the other hand, if a small rivet is used in a thick plate, the shear strength is the determining factor and there is an excess of bearing strength. Small holes in thick plate usually make fabrication difficult. Experience indicates that the rivet diameter should be not less than the thickness of the thickest plate through which it is driven.

*Spacing of Rivets:—*The spacing of rivets in any joint ordinarily depends upon the proportions of the members joined. The minimum spacing is determined by driving conditions: the space between the rivets must be sufficient to permit them to be driven without interference. Three times the nominal rivet diameter is the recommended minimum spacing. In tension members and joints, the spacing must be such that the net stressed area is not too small. In some cases this becomes the controlling consideration.

The maximum spacing of rivets in compression members may be governed by the possibility of the buckling of the component parts between rivets. In other types of members, the maximum spacing is determined usually by the designer's sense of proportion, especially, when the rivets are used simply to hold two or more plates or shapes together. As a general rule, it is recommended that the maximum distance be not greater than twenty-four times the thickness of the sheet or plate.

Edge Distance:—It already has been said that for maximum bearing strength, the edge distance measured from the center of the hole in the direction of stressing should be at least twice the diameter of the rivet hole and that the allowable bearing stress is decreased if the edge distance is less than this amount. Aside from considerations of strength, the edge distance is important because of the possibility of bulging the edge of the plate, thus causing an unsightly finished joint. Such bulging may be avoided by maintaining an edge distance of at least one and one-half times the diameter of the rivet and being careful to avoid overdriven rivets. When edge distances



Riveting Aluminum Alloy Canoe Girder, $\frac{3}{8}$ inch Hot Steel Rivets.

less than one and one-half diameters are used, the rivets generally must be underdriven to avoid bulging the plate.

Caulked Joints:—Riveted joints which must be pressure-tight may be caulked either by deforming the edges of the plates with a caulking tool or by using caulking strips of a softer alloy to seal the joint. Joints which are to be caulked in this manner should have edge distances about one and one-half times the rivet diameter or about four times the thickness of plate. The spacing of rivets should not exceed four times the rivet diameter nor about ten times the thickness of plate. The rivets ordinarily should be stressed about 20 per cent less in bearing and shear than is indicated in Tables I, II, III and IV.

In some types of riveted joints where it is not convenient to caulk in the way described, the joint often can be made pressure-tight simply by packing it with a material to act as a seal. It is important that such a material be nonabsorbent, firm enough so it will not "bleed" through the joint, and over a period of time, tough enough not to crack or spall. Such packing materials should be noncorrosive to aluminum and should be applied in layers thin enough not to appreciably affect the strength of the joint.

DRIVING METHODS FOR RIVETED JOINTS

THE driving methods for riveted joints in aluminum alloy construction do not differ greatly from those used for other metals. Because the characteristics of the various materials used for rivets differ, there is some difference in the driving methods employed for rivets made from each of the aluminum alloys as well as from steel. These differences are explained in the following paragraphs.

2S and 3S Rivets:—These relatively soft rivets always are driven cold as-received. They may be stored indefinitely without affecting their strength or driving characteristics.

A17S-T Rivets:—Rivets of A17S-T always are furnished in the heat-treated condition and are driven cold as-received. They are used ordinarily only in the $\frac{1}{4}$ -inch and smaller sizes, because they are hard to drive in the larger sizes. They are used principally as a substitute for small 17S rivets, because they eliminate some of the extra operations required for 17S rivets, such as frequent heat treatment and cold storage. While the strength of driven A17S-T rivets is not equal to that of driven 17S rivets (Table I), they are so nearly alike in strength that the A17S-T rivets have been found satisfactory for many uses, particularly in aircraft work. Rivets of A17S-T may be stored indefinitely with no change in properties.

17S Rivets:—Alloy 17S rivets always should be heat treated to obtain maximum strength. The heat treatment consists of holding the rivets at a temperature of 930° F. to 950° F. from 5 to 30 minutes, depending on the size and number, and then quenching immediately in cold water. Following this, the rivets harden gradually at room temperature, obtaining their full strength in about four days. During the first one or two hours after quenching, the rivets are relatively soft and may be driven

cold in sizes which are limited by the shape of head and equipment available, as shown by Tables V and Va.

**TABLE V—PRESSURES IN TONS REQUIRED TO DRIVE
BUTTON HEAD RIVETS WITH SQUEEZE RIVETER**

Pressures given are for complete button heads as dimensioned on page 8. Cone-point heads (Figure 1) can be cold driven with about one-third the pressures given below for cold-driven button heads. Hot-driven cone-point heads require only about one-sixth the pressures given below for hot-driven button heads.

Size, inches	Cold Driven						Hot Driven		
	2S	3S	A17S-T	17S*	53S-W	53S-T	17S 930°- 950°F.	53S 960°- 980°F.	Steel 1700°- 1900°F.
$\frac{1}{4}$	6	7	10	10	8	9	..	..	10
$\frac{3}{8}$	14	15	..	24	16	18	18	12	17
$\frac{1}{2}$	25	27	..	42	30	31	30	21	25
$\frac{5}{8}$	36	39	..	64	48	50	43	29	32
$\frac{3}{4}$	49	53	..	..	71	..	58	38	40
$\frac{7}{8}$	65	70	..	..	..	..	73	50	48
1	..	..	..	..	..	..	89	61	57

*Driven immediately after quenching.

**TABLE Va—EQUIVALENT PRESSURES FOR
PNEUMATIC HAMMERS**

These approximate equivalent pressures were determined by driving tests on aluminum alloy rivets using about 90 lb. per sq. in. air pressure, and may be used with Table V to determine the proper sizes of hammers for driving various rivets.

Bore and Stroke of Hammer, inches	Approximate Equivalent Pressure, tons	Bore and Stroke of Hammer, inches	Approximate Equivalent Pressure, tons
$1\frac{1}{16}$ x 4	14	$1\frac{1}{16}$ x 9	30
$1\frac{1}{16}$ x 6	21	$1\frac{3}{16}$ x 8	38
$1\frac{1}{16}$ x 8	27	$1\frac{3}{16}$ x 11	48

If 17S rivets are allowed to age more than two hours at room temperature after quenching, they are usually too hard to drive and must again be heat treated. Heat treatment may be repeated as often as desired without injury to the rivets. The aging can be retarded considerably by storing the quenched rivets at low temperatures. Rivets stored at 32° F. immediately after quenching remain soft enough for driving for about 36 hours. By using solid CO₂ (Dry Ice), much lower storage temperatures can be maintained and the driving period prolonged almost indefinitely. At a temperature of -50° F., for example, rivets remain soft enough for driving for a period of two weeks or more.

In the larger sizes, 17S rivets usually are driven hot. The rivets are heated at a temperature from 930° F. to 950° F. for about 15 minutes and are then inserted in the hole and driven. The quench is obtained by the contact with the relatively cold driving tools and metal around the hole. It is important that the rivets be transferred from the furnace and driven quickly in order to intensify the quenching effect and make the driving easy.

To assure the use of heat-treated rivets, 17S rivets are sometimes ordered in the fully heat-treated condition (17S-T). If some of these are not again heat treated, this can be detected by the fact that they drive only with great difficulty even in sizes as small as $\frac{1}{8}$ inch. If such rivets are driven completely, no harm is done because they will have full strength.

53S Rivets:—Rivets of this alloy may be obtained in three different tempers. The first, designated 53S, is the temper as-formed. In this temper, the rivets are relatively soft, about the same as 3S rivets, and are employed only when the rivets are to be driven hot.

The second temper, and the one most often used, is 53S-W. Rivets supplied in this temper may be driven cold, as-received, in sizes which are limited only by the shape of head and equipment available as shown in Tables V and Va. Rivets of 53S-W harden rather rapidly at room temperature for about one day

after heat treating, and more slowly thereafter. Since they are heat treated before shipment, they are usually fairly stable when received and can be stored for several months without appreciable change in characteristics. If they are stored in a warm place or for a very long time, they may harden sufficiently to decrease the ease of driving. If this occurs, they may be restored by again heat treating, the procedure being the same as the heat treatment of 17S rivets except that the temperature should be 960° F. to 980° F. Shear strengths and driving pressures of freshly heat-treated 53S-W rivets will be lower than those given in Tables I and V unless the rivets are allowed to age at least one week at room temperature before driving.

The third temper is 53S-T, which is simply 53S-W aged for about 18 hours at temperatures from 310° F. to 320° F. Because of their higher mechanical properties, it is somewhat harder to drive 53S-T rivets than 53S-W rivets and so they are not used as frequently even though they are stronger (Table I). In the smaller sizes, for which driving pressure is seldom a limiting factor, they are often found to be better than 53S-W. They may be stored indefinitely at room temperature without affecting their strength or driving characteristics.

Alloy 53S rivets are driven hot in the larger sizes if the available equipment does not permit cold driving in the W or T temper. The hot-driving procedure is the same as that for 17S rivets except that the heating temperature is from 960° F. to 980° F. For hot driving, 53S rivets are ordinarily ordered not heat treated, but 53S-W and 53S-T rivets may also be hot driven with no change of method.

Steel Rivets:—Steel rivets in aluminum alloy structures ordinarily are driven hot in the usual way. They are heated to about 1800° F. and driven with as little delay as possible so as to make the driving easier.

Where a large group of hot steel rivets occur closely spaced, it is good practice to avoid overheating the adjacent metal. Generally, the only precaution necessary is to drive at random rather than in succession. Sometimes it may be necessary to



Cold Driving $\frac{3}{4}$ inch Steel Rivets in Aluminum Alloy Truss.

cool by water or compressed air, preferably the latter. The temperature of the aluminum alloy parts never should be allowed to rise above 400° F. For the alloy 17S-T, the temperature should not be allowed to exceed 300° F. If these precautions are taken, the strength of the aluminum alloy parts will not be affected appreciably and warping will be reduced to a minimum.

Recently some success has been attained in the use of cold-driven annealed steel rivets in aluminum alloy structures. It has been found that the $\frac{3}{4}$ -inch size will drive satisfactorily by using a cone-point type of head and about 50 tons pressure; a shear strength of about 40,000 lb. per sq. in. is developed. Before driving, the rivets should be thoroughly annealed at about 1300° F., and should be cooled slowly in the furnace.

Pressures Required to Drive:—The pressure required to drive rivets depends upon the size, the type of head, the rivet material and the driving temperature. It varies roughly as the square of the diameter of the finished driven head, so that a

small head has a considerable advantage over a larger one. Tests have shown that the button head, the smallest type shown on page 8, is larger than necessary to develop the strength of the rivet shank. Therefore, where ease of driving is important and where a large head size is not needed for appearance or other reasons, undersize sets should be used for the driven heads to decrease the required driving pressure.

There is often some confusion between the round head and button head shown on page 8. The round head is the larger of the two and in view of the foregoing discussion, preference should always be given to the smaller button head. Of course the shape of the manufactured head, round or button, does not necessarily determine the shape of the driven head, but too often it is found necessary to try to match the shape of the manufactured head in the driven head. This causes considerable difficulty if round-head rivets are used because they require about 30 per cent more pressure to drive than button head rivets.

After considerable research on the factors influencing driving pressure, the cone-point type of driven head shown in Figure 1 has been developed for use on aluminum alloy rivets. This head is large enough to develop the tensile strength of the rivet shank in a straight tensile pull, and yet is so small that it requires only one-third the driving pressure of a full button head, as indicated in Table V. The cone-point head has the additional advantage of requiring less stock, as indicated in Table VI, and it is not greatly affected in appearance or strength by slight variations in length of shank. Several sizes of rivets may be driven with a given cone-point rivet set as indicated in Figure 1.

The degree of upsetting for cone-point head rivets is best con-

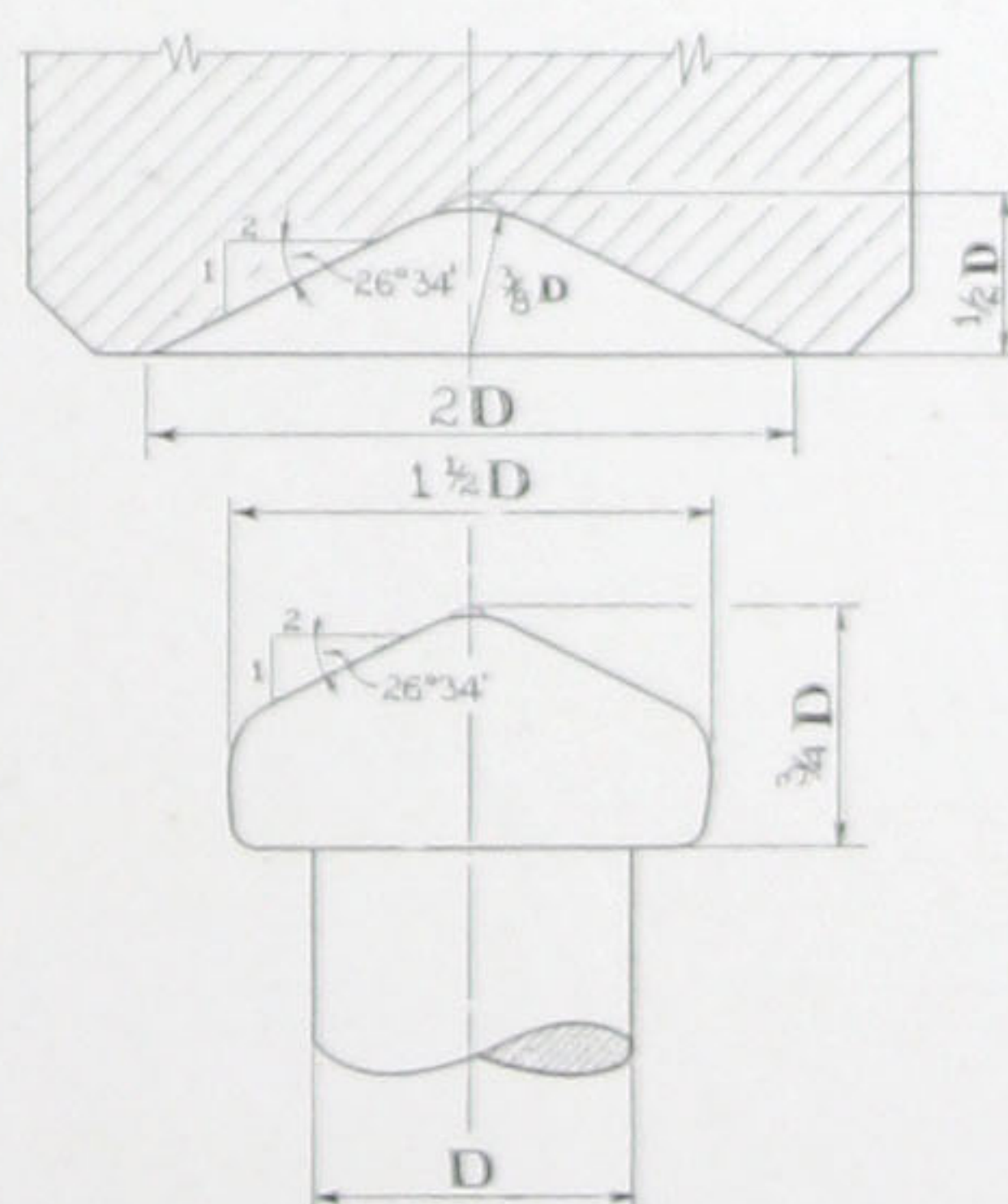


FIGURE 1. Nominal dimensions of cone-point head and rivet set.

trolled by checking the diameters of the driven heads and keeping these as close as possible to 1.5 times the nominal shank diameter. If the rivets are cut to approximately the correct length (Table VI, see note for cone-point heads) and the diameter of the driven head is controlled, the other head dimensions will require no attention.

Table V, page 17, gives pressures required to drive full button heads and cone-point heads with a squeeze riveter. This table may be used as a guide in comparing the driving characteristics of the different rivets and in selecting equipment for driving.

Excessive pressures used in driving may result in any or all of the following difficulties: bulging of the edge of the piece being riveted, buckling or other distortion, particularly if thin material is being used, and weakening or fracturing of metal adjacent to the hole. Overdriving of rivets should always be avoided.

Riveting Equipment:—Squeeze riveters generally are preferable to other types for driving rivets in aluminum. Their use assures properly upset shanks and well-centered heads. The capacity required may be determined by reference to Table V.

Pneumatic hammers are suitable for riveting aluminum alloy

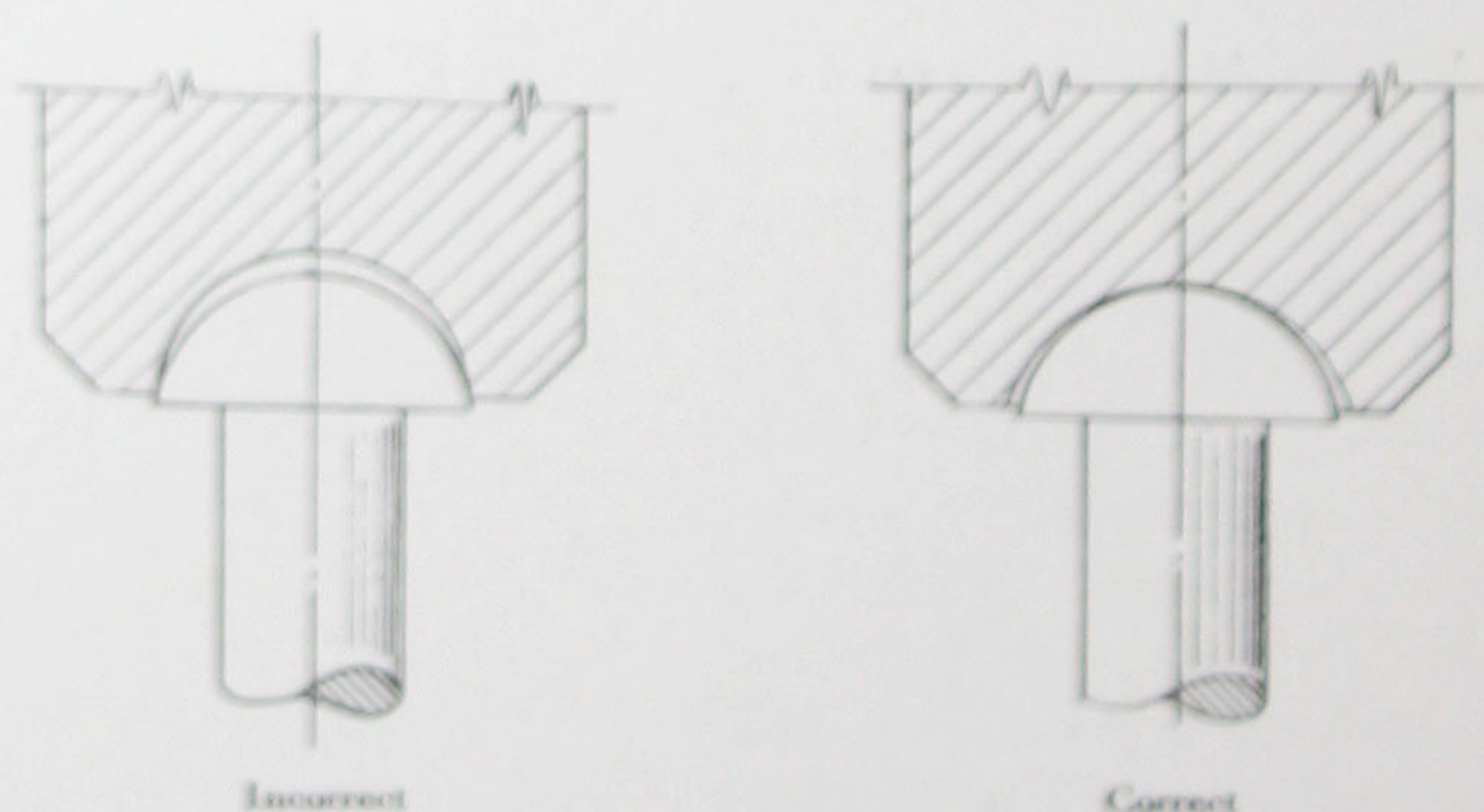


FIGURE 2. Sketch showing the incorrect and correct fit of the backing tool on the manufactured head.

TABLE VI (Continued)—LENGTH OF RIVETS FOR VARIOUS CRIPS

U.S. rivets in U.S.-T plates, bottom bands

For conical bands deduct one-half diameter.

Plate dimension $\frac{1}{4}$ inch greater than rivet diameter.

Crip	Diameter of Rivet				
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1
	$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$	$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$	$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$	$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$	$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$
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Because of variations in rivet sets and driving conditions, it is well to check these lengths by actual driving tests before specifying the exact length of rivets.

structures, provided they are large enough to upset the rivets properly. Driving tests on aluminum alloy rivets indicate that the various sizes of hammers will develop equivalent pressures as indicated in Table Va when used with about 90 lb. per sq. in. air pressure.

The values from Table Va may be used in conjunction with Table V as a guide in the selection of equipment. If it is desired to select a hammer for use on $\frac{1}{2}$ -inch 53S-W cold-driven rivets, Table V shows that this rivet requires 30 tons, using a squeeze riveter for a complete button head, or about 10 tons ($\frac{1}{3}$ of 30) if a cone-point head is used. Judging from the equivalent pressures given in Table Va, a hammer $1\frac{1}{16}$ x 9 inches would be selected for button heads, and a hammer $1\frac{1}{16}$ x 4 inches would be selected for cone-point heads.

The values of equivalent pressure will be found somewhat low when applied to hot-driven steel rivets, probably because steel rivets hold their heat better than aluminum alloy rivets during the driving operation. The sizes of hammers required for driving hot steel rivets are too well known in fabricating shops to require further comment.

Aluminum alloy rivets may be headed by means of a heavy hand hammer or sledge. This method has been found satisfactory for work which permits adequate bucking.

Rivet sets for use on aluminum alloy rivets should have smooth, polished surfaces so that the metal may flow readily during the forming of the head. The bucking tools, especially those used with the larger hammers, should have plenty of mass. The mass should be distributed close to the rivet head, and be concentric with it. The cup on the bucking-up set should be slightly wider and shallower than the manufactured head so that the initial contact will be at the end of the head directly in line with the shank, as shown in Figure 2. This practice will prevent the shank from being driven up into the head, and will greatly facilitate uniform upsetting throughout the length of the shank.

For heat treating aluminum alloy rivets, a reliable temperature indicator is essential in order to insure the required

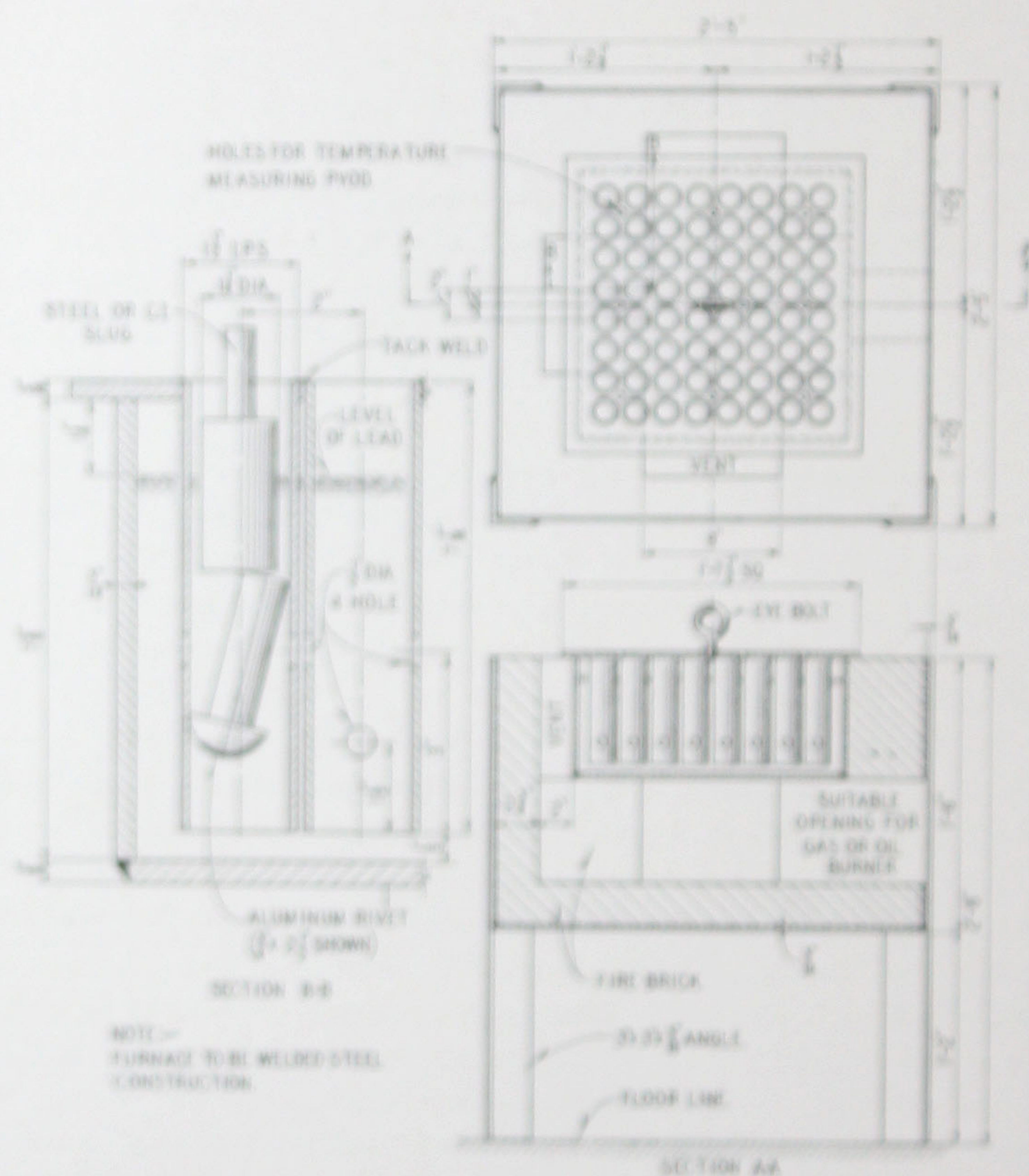


FIGURE 3. Lead pot for heating aluminum alloy rivets for hot driving.

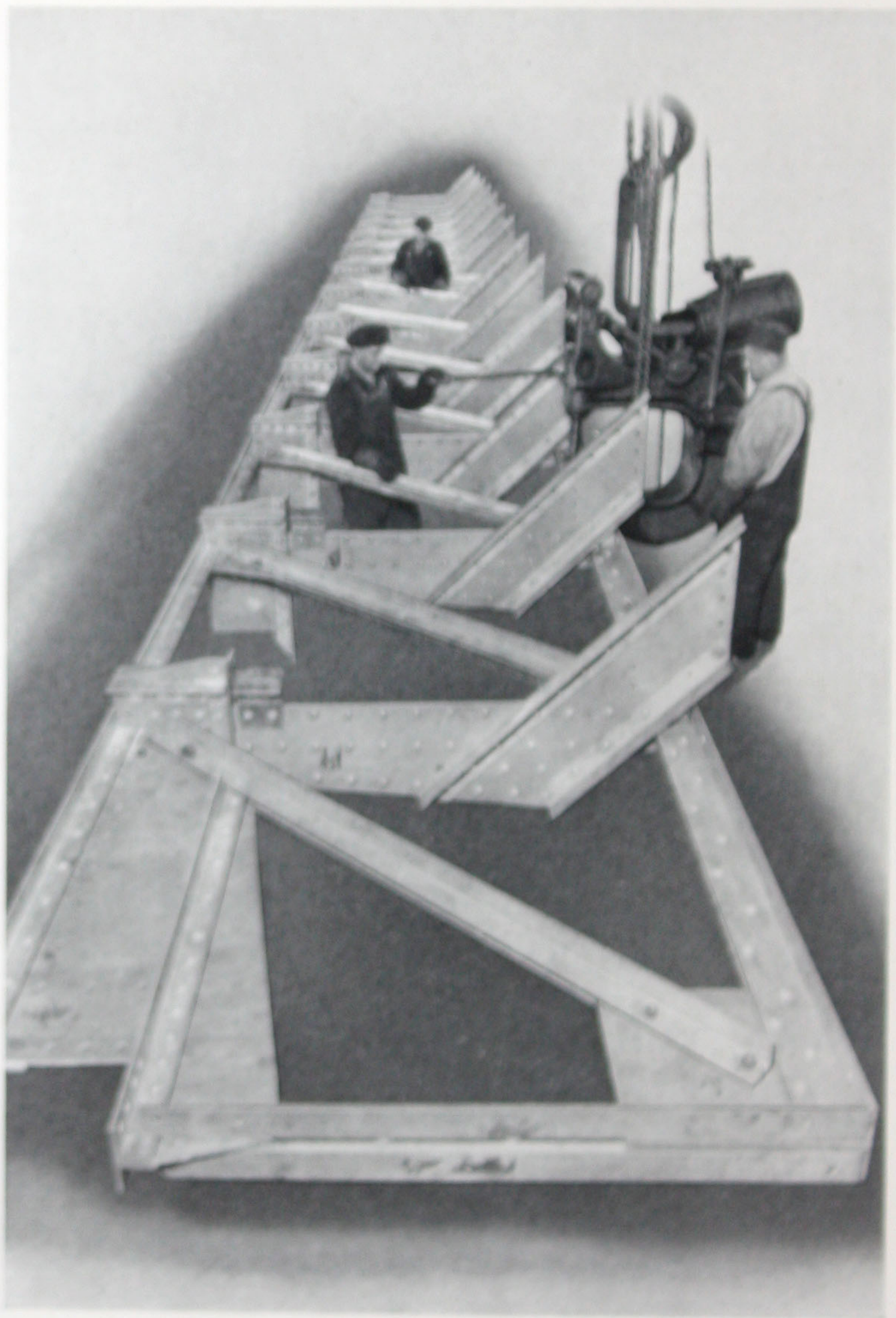
temperature control. When rivets are to be quenched in water for cold driving, the heating equipment generally consists of a bath of sodium nitrate heated by gas, oil or electricity. The rivets are handled in a basket made of wire mesh or perforated sheet and must be quenched quickly after removal from the heating bath. All nitrate must be washed off the rivets.

It is often desirable to avoid having the rivets directly in contact with the nitrate, and tanks for heat treating rivets are often equipped with steel tubes, closed at one end and immersed in the nitrate with the open end projecting slightly. The open end is fitted with a readily removable cap. The rivets are heated by placing them inside these protecting tubes for about one-half hour. At the end of the heat-treatment period the cap is removed, the tube quickly withdrawn from the bath, and the rivets immediately poured into the quench water. Electrically-heated air furnaces also may be used to avoid having the rivets in nitrate, but care should be taken in such furnaces to have the temperature uniform throughout.

Aluminum alloy rivets for hot driving are commonly heated in a lead pot such as the one shown in Figure 3, or in an electrically-heated air furnace. Automatic control of temperature is highly desirable in both types of equipment. The heating equipment must be near the work so that the temperature lost in transfer is minimized. When heating in a lead bath, provision must be made to submerge the rivets in the bath; otherwise they will float. All adhering lead should be removed by a sharp blow against some solid object, before the rivet is inserted in the hole.

Rivet Holes:—Rivet holes in aluminum alloys may be punched, drilled, or sub-punched and reamed to size. The last method is preferable, especially if the reaming is done in assembly to give the holes exact coincidence. It has been found that bridge reamers of the spiral-fluted type are best suited for use in aluminum and aluminum alloys.

The clearance which is to be allowed in the holes depends largely on the class of work. It is easier to drive rivets, espe-



Riveting Aluminum Alloy Truss, $\frac{3}{4}$ inch Hot 178 Rivets.

cially those cold driven, when the clearance is small. If a loose fit is used, it will be hard to hold the rivets straight, and eccentric heads often result. The best clearance is the smallest one which will allow the rivet to be inserted easily without delay. Hot rivets require more clearance than cold ones because it is harder to handle them.

Rivet holes tend to get out of coincidence during the driving operation because of slippage, swelling of the metal, and warping caused by heat. For this reason, the work should be assembled firmly by bolts before driving. The bolting should be tight to prevent slippage and to prevent the rivets from squeezing out between the parts of the joint.

Lengths of Rivets:—The length of rivet required for forming a head depends upon the grip or total thickness of metal through which the rivet is driven, clearance between rivet and rivet hole, the alloy, and the form of head. Table VI gives the lengths for various grips for full button heads on 17S rivets driven in 17S-T plate. The values in this table are accurate only for the conditions stated, but they may be used to estimate lengths required for other conditions. Because of variations in rivet sets and driving conditions, the safest method to follow is to make several trials with the equipment to be used on the job before specifying the exact length of rivets. It is better to have the rivets slightly too long rather than too short, because a short rivet may allow the rivet set to strike and damage the plate.

SELECTION OF RIVET ALLOY

THE proper rivet to use in any aluminum alloy structure depends upon many factors; consequently each application must be considered in the light of its own requirements. The following paragraphs cover some of the more general points influencing the selection of an alloy and present certain combinations which have been found to be satisfactory.

If an attempt is made to drive a hard rivet such as 17S into a soft plate such as 3S-O, the plate will be unduly distorted and the resulting appearance poor. Also, the strength of the rivet is likely to be governed by its bearing value against the soft plate so that the shear strength of the rivet may be largely wasted. For these reasons, it is poor practice to use a hard rivet in a soft alloy.

A soft rivet can sometimes be used to advantage in a hard alloy, especially if the joint is not highly stressed. It is generally advantageous to use a rivet having about the same properties as the material in which it is driven.

Steel rivets should be used only where the finished structure is to be painted thoroughly and maintained, because rust stains are likely to mar the appearance of the structure if bare steel is exposed. Properly protected steel rivets are satisfactory in many kinds of aluminum construction.

The following combinations of structure and rivets have been found to work together satisfactorily in ordinary structures:

Structure	Rivets
2S, any temper	2S
3S-O, 4S-O, 52S-O	3S
5S, 4S, 52S, quarter hard or harder	3S, 53S-W
A17S-T, 17S-T	A17S-T, 17S, Steel
51S-W, 51S-T, 53S-W, 53S-T	53S-W, 53S-T, Steel

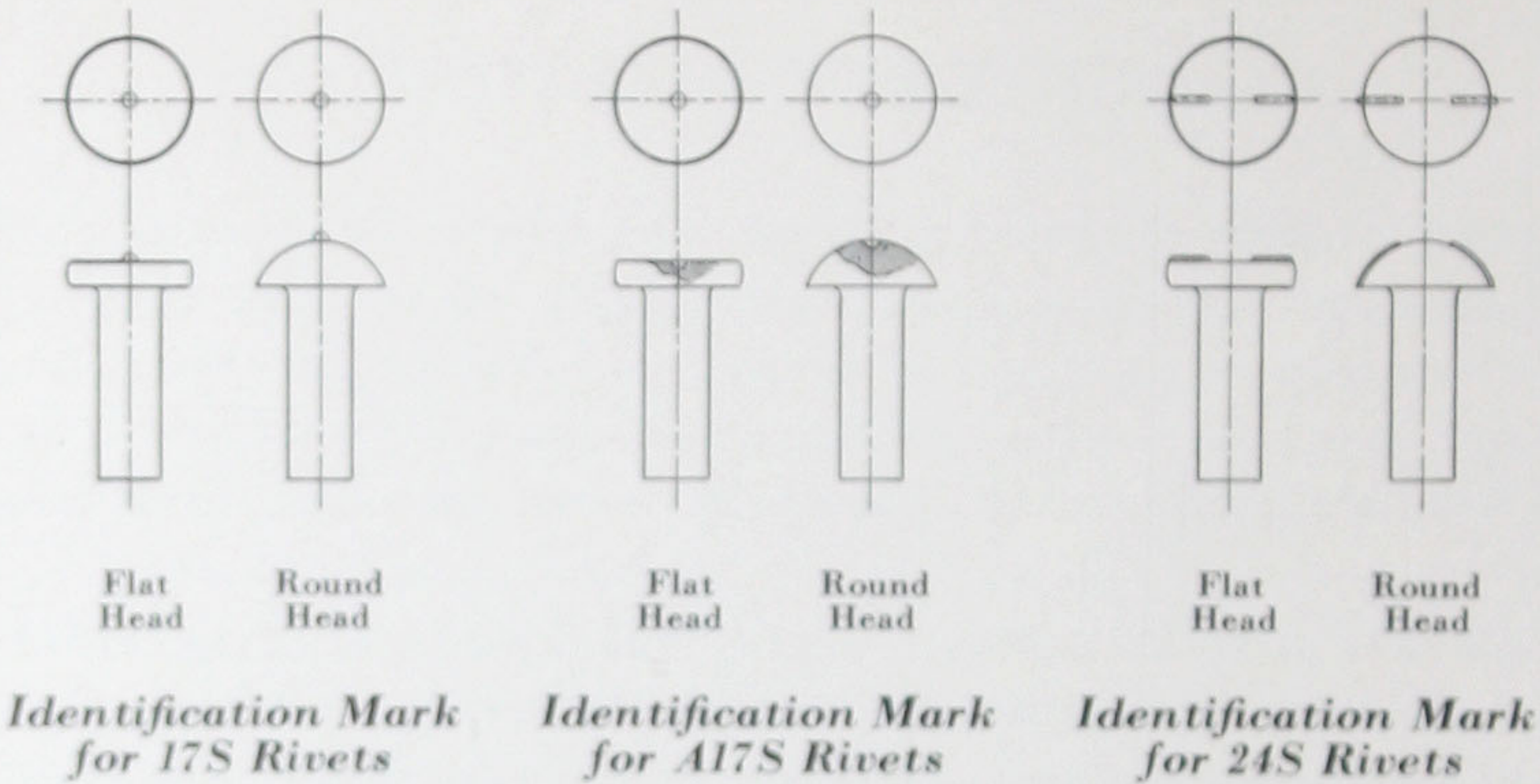
AIRCRAFT RIVETING

THE riveting of aircraft is limited to the smaller sizes of rivets and consequently it is nearly always done cold. The most commonly used rivet is 17S driven immediately after quenching. These rivets develop an ultimate shear strength, based on the area of the hole, of 35,000 lb. per sq. in. about four days after being driven.

Where a shear strength higher than that of 17S is needed, 24S rivets are sometimes used. Driven immediately after quenching from a temperature of 910° F. to 930° F., they develop within about one day an ultimate shear strength of about 44,000 lb. per sq. in. based on the area of the hole. Since the rate of age-hardening of 24S rivets is more rapid than that of 17S rivets, it is necessary to drive them more quickly after quenching; the elapsed time should not exceed 20 minutes. Rivets of 24S are more difficult to drive than those of 17S. They are not regularly carried in stock and may not always be obtained as promptly as rivets in the other alloys.

Rivets of A17S-T, 53S-W or 53S-T, driven in the as-received condition, are being used more and more in aircraft construction to avoid shop heat treating, refrigeration and similar operations involved in the use of 17S and 24S rivets. These rivets develop ultimate shear strengths somewhat less than that of 17S (Table I) but are found to be quite satisfactory for many purposes. They drive as readily as 17S rivets (Table V) and can be driven much more easily than 24S rivets.

When bare Alclad 17S-T or Alclad 24S-T sheet is used, 53S-W or 53S-T rivets are the most satisfactory because they have the best inherent resistance to corrosion of any of the foregoing rivets, and in addition, they have substantially the same electrolytic potential as the Alclad coating. Under severely corrosive conditions, the heads of A17S, 17S and 24S rivets tend to be protected electrolytically by the Alclad coating. Rivets of 53S-W and 53S-T do not show this tendency and hence their use insures longer life to the coating in the vicinity of the rivet.



Identification markings have been adopted for use on the heads of aircraft rivets of the following alloys: 17S, A17S and 24S. These markings are illustrated above. No identification marks have yet been adopted for rivets of the other alloys.

Certain sizes of aluminum alloy rivets can now be supplied with the shank ends chamfered as shown in the sketch below. This chamfer simplifies the insertion of the rivet into the hole, particularly with automatic riveting machines.

A = Shank Diameter
B = Diameter of End
C = Length of Radius

Formulas

$C = .25 \times A$
 $\text{Radius} = .3125 \times A$

Diameter of Rivet Inches	B Inches
$\frac{1}{16}$	.047
$\frac{3}{32}$	.071
$\frac{1}{8}$	.092
$\frac{5}{32}$	.118
$\frac{3}{16}$	.137
$\frac{1}{4}$	.185

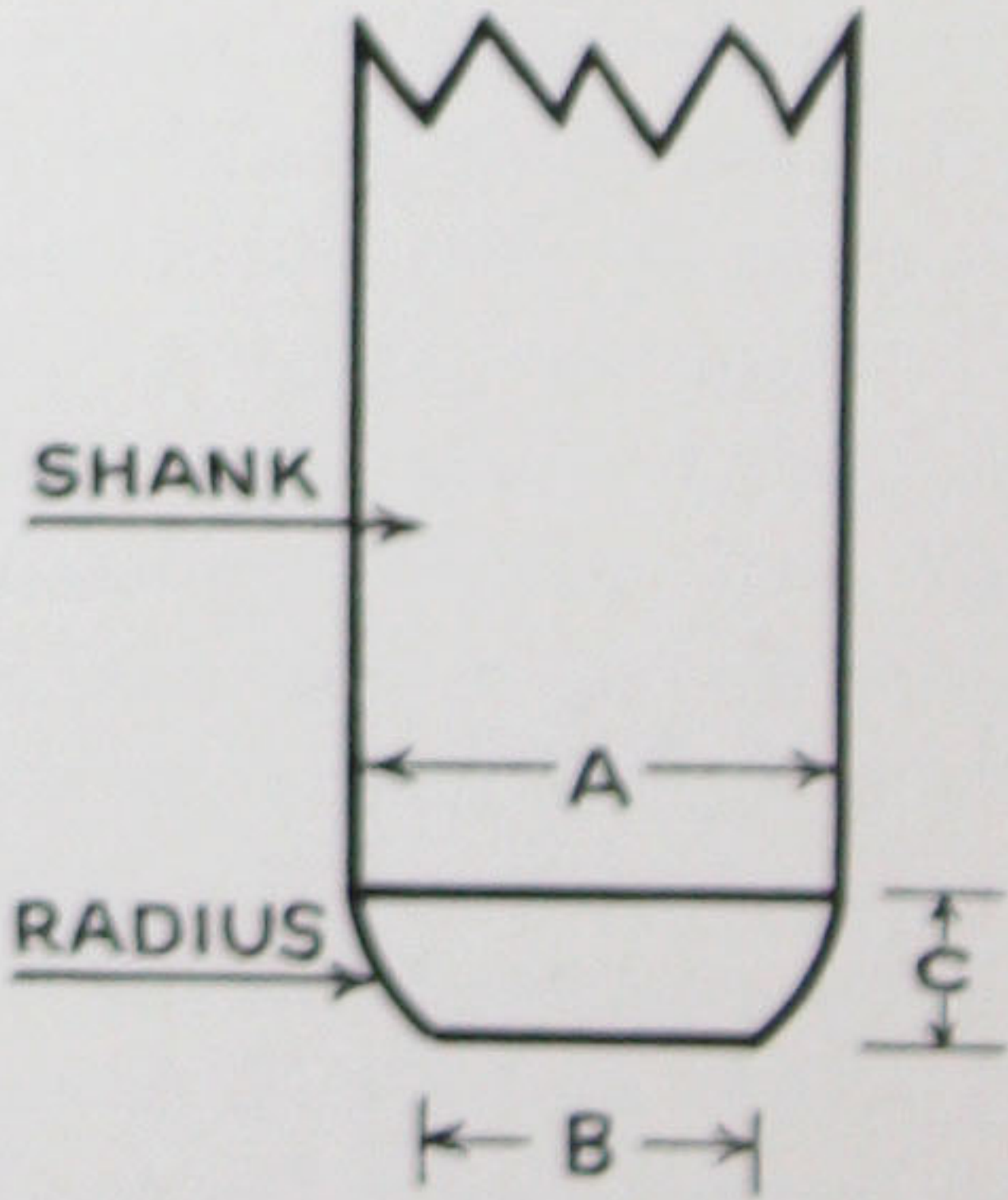


TABLE VII—WEIGHT* OF BUTTON HEAD
ALUMINUM ALLOY RIVETS

Values given in pounds per hundred rivets

Length Under Head, inches	Diameter in Inches										
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
0**	0.2	0.4	0.6	0.9	1.4	2.8	4.8	7.6	11.3	16.1	22.1
$\frac{1}{2}$	0.4	...	...	...	...	..	..	..	..	..	..
$\frac{5}{8}$	0.5	0.9	...	...	...	..	..	..	..	..	..
$\frac{3}{4}$	0.6	1.0	1.4	...	...	..	..	..	..	..	..
$\frac{7}{8}$	0.6	1.1	1.6	2.2	...	..	..	..	..	..	..
1	0.7	1.2	1.7	2.4	3.4	..	..	..	..	..	..
$\frac{1}{8}$	0.8	1.3	1.9	2.6	3.6	..	..	..	..	..	..
$\frac{1}{4}$	0.8	1.4	2.0	2.8	3.9	7	..	..	..	..	..
$\frac{3}{8}$	0.9	1.5	2.1	3.0	4.1	7	..	..	..	..	..
$\frac{1}{2}$	0.9	1.6	2.3	3.2	4.4	7	12	..	..	..	..
$\frac{5}{8}$	1.0	1.7	2.4	3.4	4.6	8	12	..	..	..	..
$\frac{3}{4}$	1.1	1.8	2.6	3.6	4.9	8	13	18	..	..	..
$\frac{7}{8}$	1.1	1.9	2.7	3.8	5.1	9	13	19	..	..	..
2	1.2	2.0	2.8	3.9	5.4	9	14	20	27	..	..
$\frac{1}{8}$	1.2	2.0	3.0	4.1	5.6	9	14	21	28	..	..
$\frac{1}{4}$	1.3	2.1	3.1	4.3	5.9	10	15	21	29	39	..
$\frac{3}{8}$	1.4	2.2	3.3	4.5	6.1	10	15	22	30	40	..
$\frac{1}{2}$	1.4	2.3	3.4	4.7	6.4	11	16	23	31	41	53
$\frac{5}{8}$	1.5	2.4	3.5	4.9	6.6	11	17	24	32	42	55
$\frac{3}{4}$	1.6	2.5	3.7	5.1	6.9	11	17	24	33	44	56
$\frac{7}{8}$	1.6	2.6	3.8	5.3	7.1	12	18	25	34	45	58
3	1.7	2.7	3.9	5.5	7.3	12	18	26	35	46	59
$\frac{1}{8}$	1.7	2.8	4.1	5.7	7.6	13	19	27	36	47	61
$\frac{1}{4}$	1.8	2.9	4.2	5.8	7.8	13	19	27	37	49	62
$\frac{3}{8}$	1.9	3.0	4.4	6.0	8.1	13	20	28	38	50	64
$\frac{1}{2}$	1.9	3.1	4.5	6.2	8.3	14	20	29	39	51	65
$\frac{5}{8}$	2.0	3.2	4.6	6.4	8.6	14	21	30	40	52	67
$\frac{3}{4}$	2.0	3.3	4.8	6.6	8.8	14	22	30	41	54	69
$\frac{7}{8}$	2.1	3.4	4.9	6.8	9.1	15	22	31	42	55	70
4	2.2	3.5	5.1	7.0	9.3	15	23	32	43	56	72
$\frac{1}{8}$	2.2	3.6	5.2	7.2	9.6	16	23	33	44	58	73
$\frac{1}{4}$	2.3	3.7	5.3	7.4	9.8	16	24	33	45	59	75
$\frac{3}{8}$	2.4	3.8	5.5	7.6	10.1	16	24	34	46	60	76
$\frac{1}{2}$	2.4	3.9	5.6	7.7	10.3	17	25	35	47	61	78
$\frac{5}{8}$	2.5	4.0	5.8	7.9	10.6	17	25	36	48	63	79
$\frac{3}{4}$	2.5	4.1	5.9	8.1	10.8	18	26	36	49	64	81
$\frac{7}{8}$	2.6	4.2	6.0	8.3	11.1	18	27	37	50	65	82
5	2.7	4.3	6.2	8.5	11.3	18	27	38	51	66	84

*Weights given are for 17S.

For 2S multiply by 0.971—For 3S multiply by 0.983—For A17S multiply by 0.989—For 53S multiply by 0.965.

**Weights of rivet heads only.

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